

Engagement Opportunities in NASA STEM 2022 (EONS-2022)
NASA Research Announcement (NRA)
MUREP PBI/HBCU Data Science Equity, Access and Priority in Research and Education
(MUREP DEAP)
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Title: Effects of Gravity on Creeping Salts and Salt Mixtures: Developing Image-based and AI-enhanced Diagnostics for Determining Chemical Compositions

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Summary: Salty oceans, underground brines, and even faint water signatures are among the most interesting targets for space exploration and the search for non-terrestrial life. Recently, the James Webb Space Telescope discovered water in the atmosphere of the exoplanet WASP-96b and, while Mars and Venus have lost most of their water, Mars' surface geology still loudly echoes its wet history. Ongoing and future NASA missions have set their sight on the salty oceans and deposits on the ice-crust moons Europa and Enceladus. Water is also a critical resource for future Lunar and Martian bases as illustrated by the International Space Station (ISS) which can recycle only 70% of its wastewater. Water exploration from ores and underground brines, ultra-efficient recycling, as well as space agriculture will handle concentrated salt solutions with likely operational problems such as clogging of pipes, crust formation, and corrosion that reduced gravity conditions could worsen. The science of concentrated salt solutions and the formation of evaporites is intriguing and complicated. In this context, salt creep is an iconic but deleterious effect which describes the ability of certain solutions to spread during drying and even climb up over solid surfaces. Other salts create dendritic evaporites, ring-like deposits ("coffee stain rings") or shrink their footprint during drying. These complex dynamics, the variety of patterns, and the multitude of underlying mechanisms make salt creep and similar deposit patterns a hard problem for soft matter science and are—together with only sparsely available experimental data—the main obstacles for reliable predictions and theoretical understanding.

Our team will utilize machine learning (ML) and artificial intelligence (AI) to end this century-old impasse. Neural networks and deep-learning strategies are uniquely suited for the analysis of image patterns and can be expected to perform exceedingly well given a sufficiently large database of evaporite photos. In this project, we will compile a database of 500,000 images using a novel robotic drop imager (RODI) and employ these images as both training and test sets for our ML/AI approach. This important data science portion, coined "Image to Composition" or I2C, will ultimately predict chemical constituents and experimental conditions from simple photos of dried inorganic solutions. We will also identify method limitations and demonstrate cursory but safe analyses of laboratory/environmental spills and leakages solely from photos. Our trained and tested deep-learning network will enhance NASA missions that do not permit heavy suites of analytical instruments. In addition, we will study gravity effects on evaporating solutions by complementing Earth-bound experiments with acoustic levitation coupled to spectroscopic techniques and microgravity conditions. For this, we will construct an autonomous, shoebox-sized version of RODI and employ it on parabola flights (and an envisioned, future suborbital flight) to determine the role of gravity on patterns formed

by drops of drying solutions. All these activities will be complemented by conventional analyses and yield benchmark data for quantitative theories. Our team brings together expertise in ultrasonic levitation, infrared spectroscopy, and astrochemistry (Florida A&M U), computer science, artificial intelligence, and pattern recognition (Bowie State U), nonequilibrium self-organization of polycrystalline solids (Florida State U), and rheology, soft matter, and microgravity science (via collaboration with NASA Glenn). We are committed to recruit and train students from underrepresented groups and plan outreach initiatives such as the participation in community festivals, social-media activity, and project-related class visits at underserved K-12 schools. Furthermore, a dedicated website will provide tutorials, updates, team-member profiles, and public access to our image database.